Title: CPT symmetric universe

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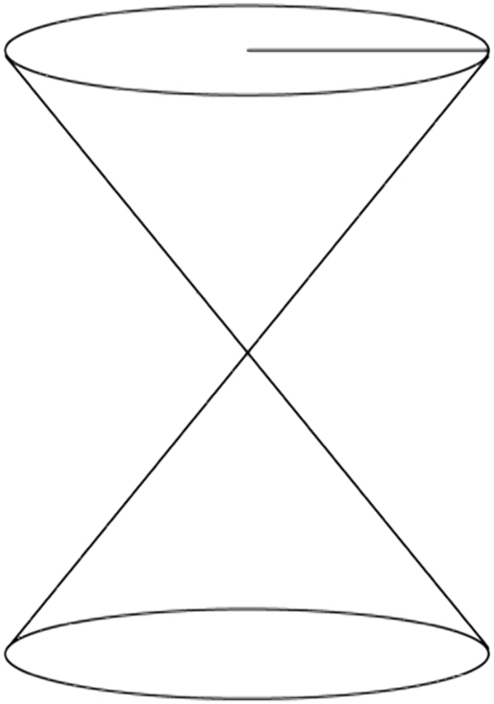
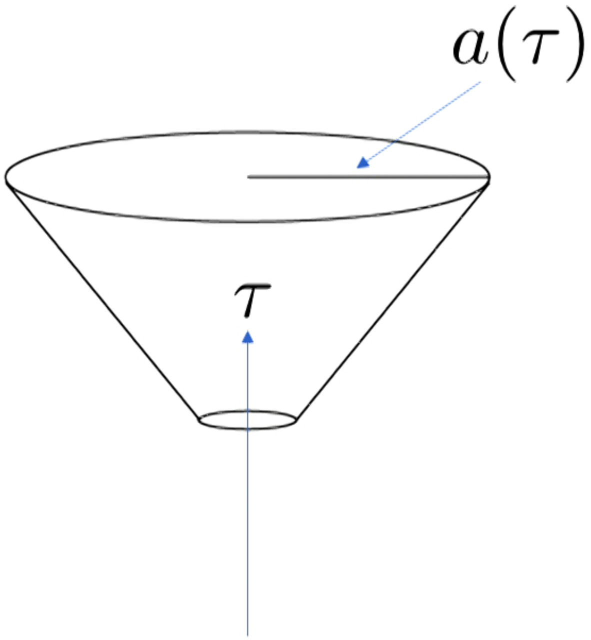
Abstract: <p>I will introduce our recent proposal that the state of the universe does *not* spontaneously violate CPT. Instead, the universe before the Big Bang is the CPT reflection of the universe after the bang. Phrased another way, the universe before the bang and the universe after the bang may be re-interpreted as a universe/anti-universe pair, created from nothing. CPT selects a unique vacuum state for the QFT on such a spacetime, which leads to a new perspective on the cosmological baryon asymmetry, and a new explanation for the observed dark matter abundance. In particular, if we assume that the matter fields in the universe are described by the standard model of particle physics (including right-handed neutrinos), we predict that one of the heavy neutrinos is stable, and that its density automatically matches the observed dark matter density if its mass is 4.8 x 10^8 GeV. Among other predictions, we have: (i) that the three light neutrinos are majorana; (ii) that the lightest of these is exactly massless; and (iii) that there are no primordial long-wavelength gravitational waves. I will mention connections to the strong CP problem and the arrow of time. (Based on arXiv:1803.08928 and arXiv:1803.08930, with Kieran Finn and Neil Turok.)</p>

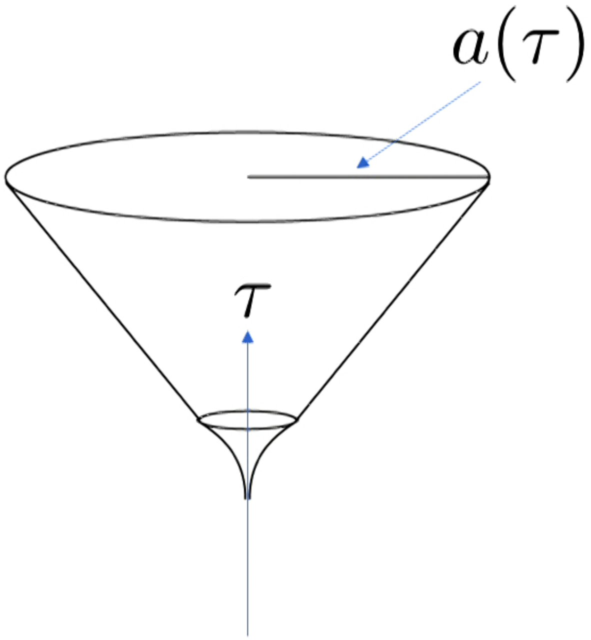


CPT symmetric universe

Latham Boyle, Kieran Finn and Neil Turok

based on
arXiv:1803.08928
arXiv:1803.08930
(arXiv:1803.11554)


$a(\tau)$
τ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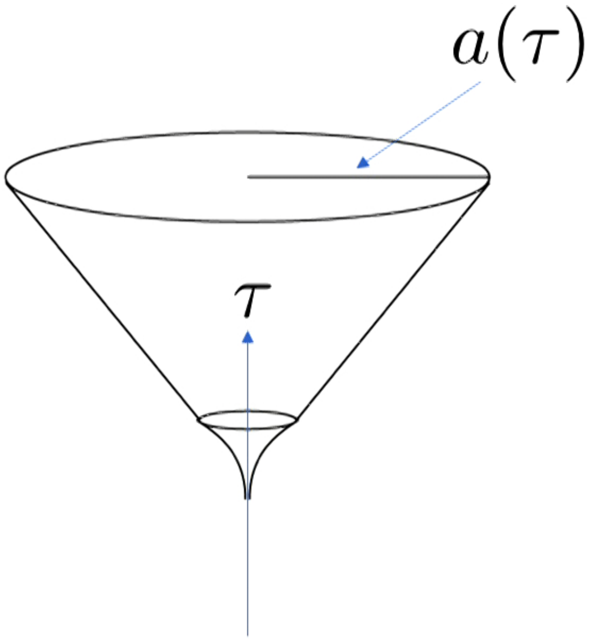
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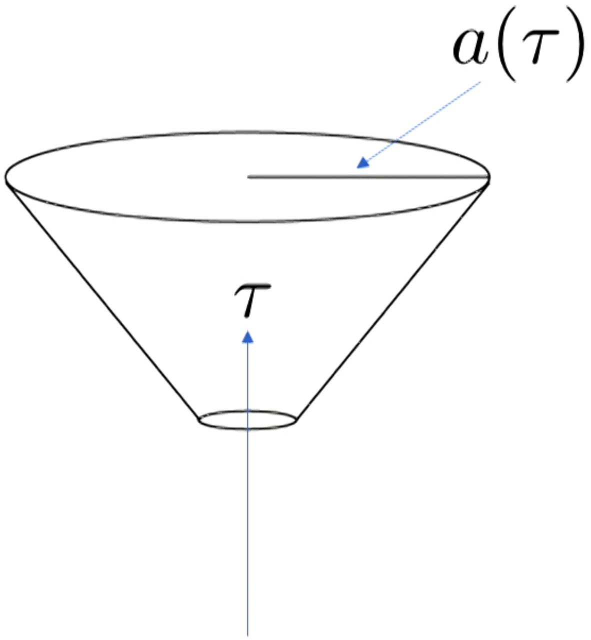
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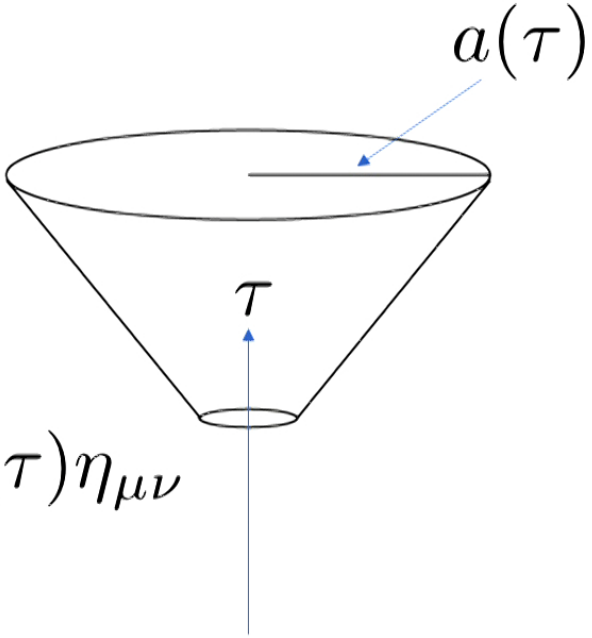
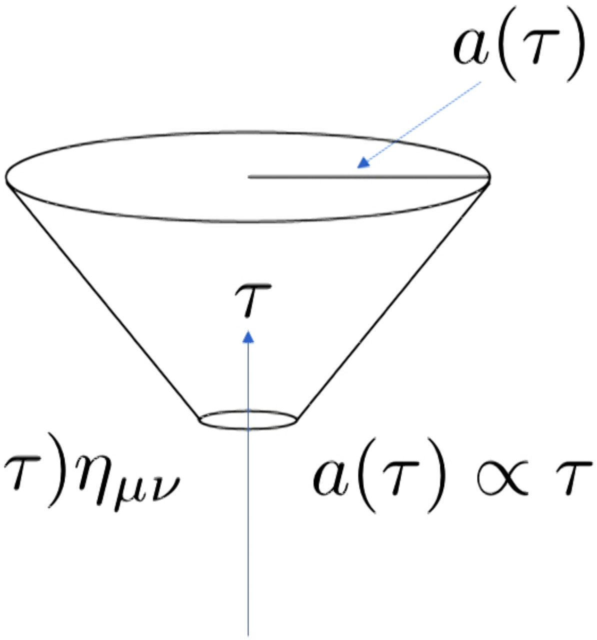
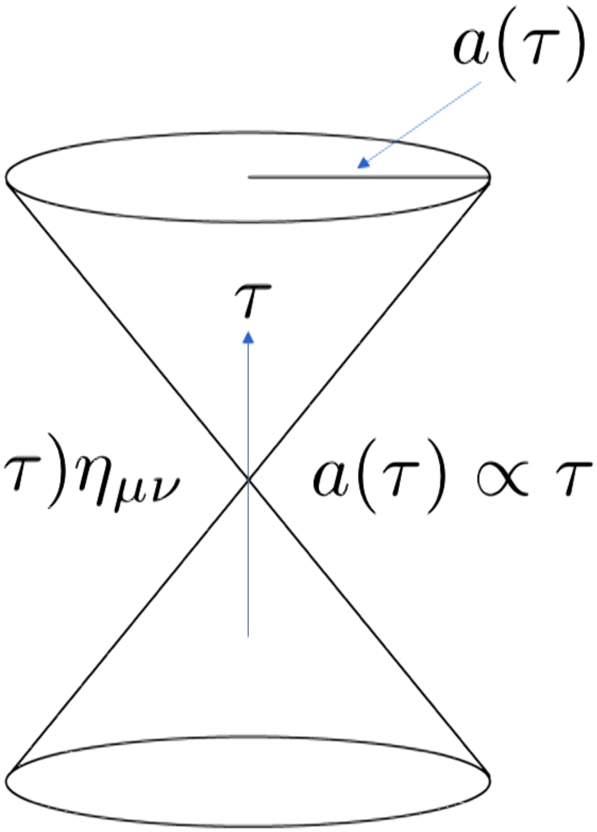


$$g_{\mu\nu} = a^2(\tau)\eta_{\mu\nu}$$



$$g_{\mu\nu} = a^2(\tau)\eta_{\mu\nu}$$

$$a(\tau) \propto \tau$$



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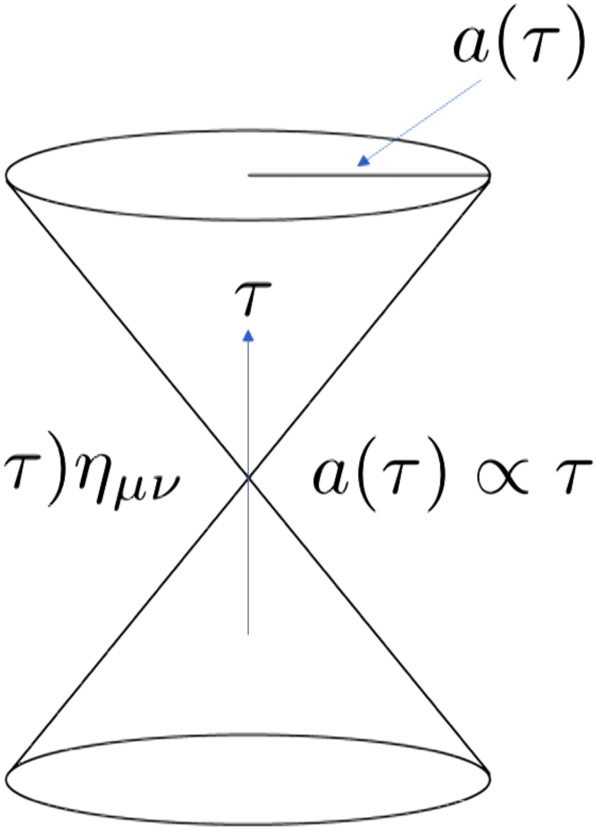

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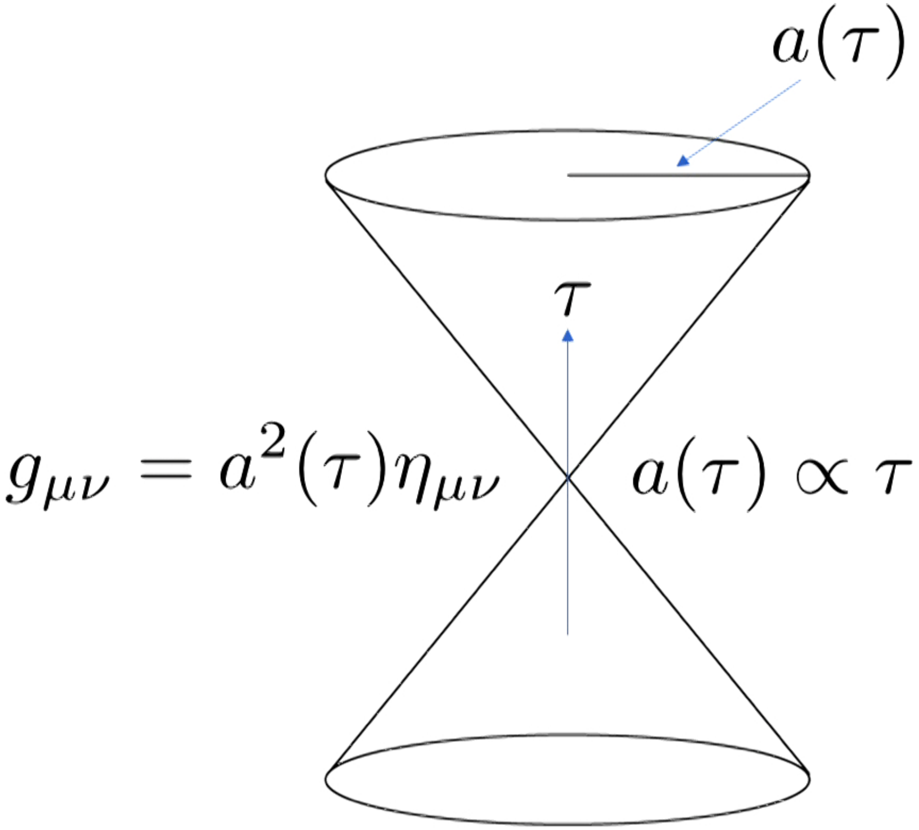
new isometry:

$$\tau \rightarrow -\tau$$



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preferred vacuum:

$$|0_{CPT}\rangle$$

$$\begin{aligned} L &= \sqrt{-g}[i\bar{\Psi}e_a^\mu\gamma^a\nabla_\mu\Psi - m\bar{\Psi}\Psi] \\ &= i\bar{\psi}\not{\partial}\psi - \mu\bar{\psi}\psi \qquad\qquad (\psi \equiv a^{3/2}\Psi, \quad \mu \equiv am) \end{aligned}$$

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\end{aligned}
$$

$$
\psi(x) = \sum_{h}\int \frac{d^3\mathbf{p}}{(2\pi)^{3/2}}[a(\mathbf{p},h)\psi(\mathbf{p},h,x) + b^{\dagger}(\mathbf{p},h)\psi^{c}(\mathbf{p},h,x)]
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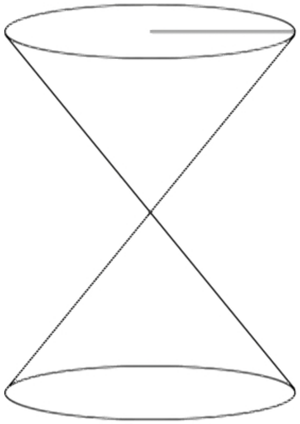

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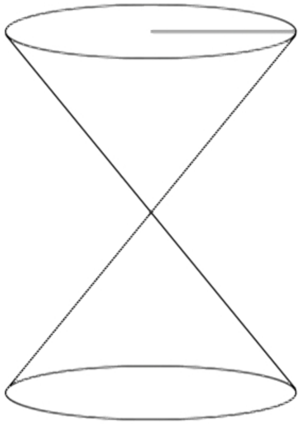

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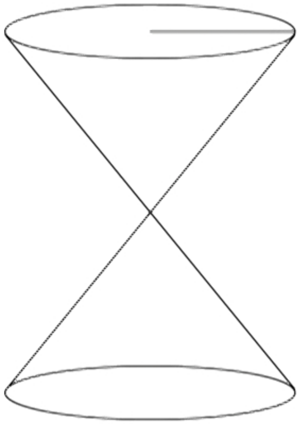

$\psi_+(\mathbf{p},h,x)$

$a_-, b_- \ \Rightarrow \ |0_-\rangle$

$\psi_-(\mathbf{p},h,x)$

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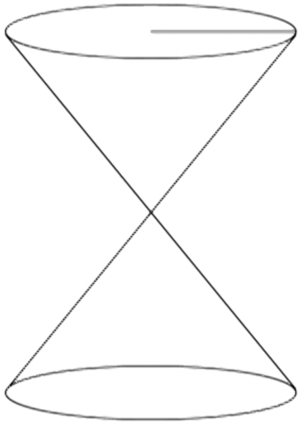

$\psi_+(\mathbf{p},h,x)$

$$\psi_0(\mathbf{p},h,x) = \frac{\psi_+(\mathbf{p},h,x) + \psi_-(\mathbf{p},h,x)}{2\cos\chi(\mathbf{p})}$$

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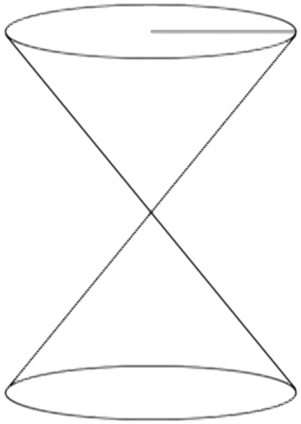
$a_{0}, b_{0} \;\Rightarrow\; |0_{0}\rangle$

$a_{-}, b_{-} \;\Rightarrow\; |0_{-}\rangle$



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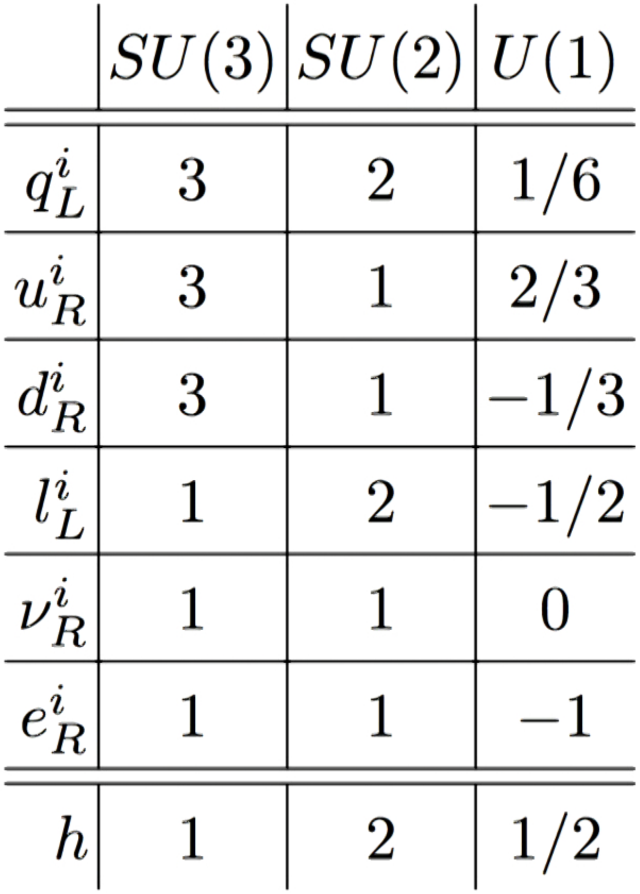
$$\langle 0_0|a^{\dagger}_{+}(\mathbf{p},h)a_{+}(\mathbf{p},h)|0_0\rangle = \sin^2\chi(\mathbf{p})$$



	$SU(3)$	$SU(2)$	$U(1)$
q_L^i	3	2	$1/6$
u_R^i	3	1	$2/3$
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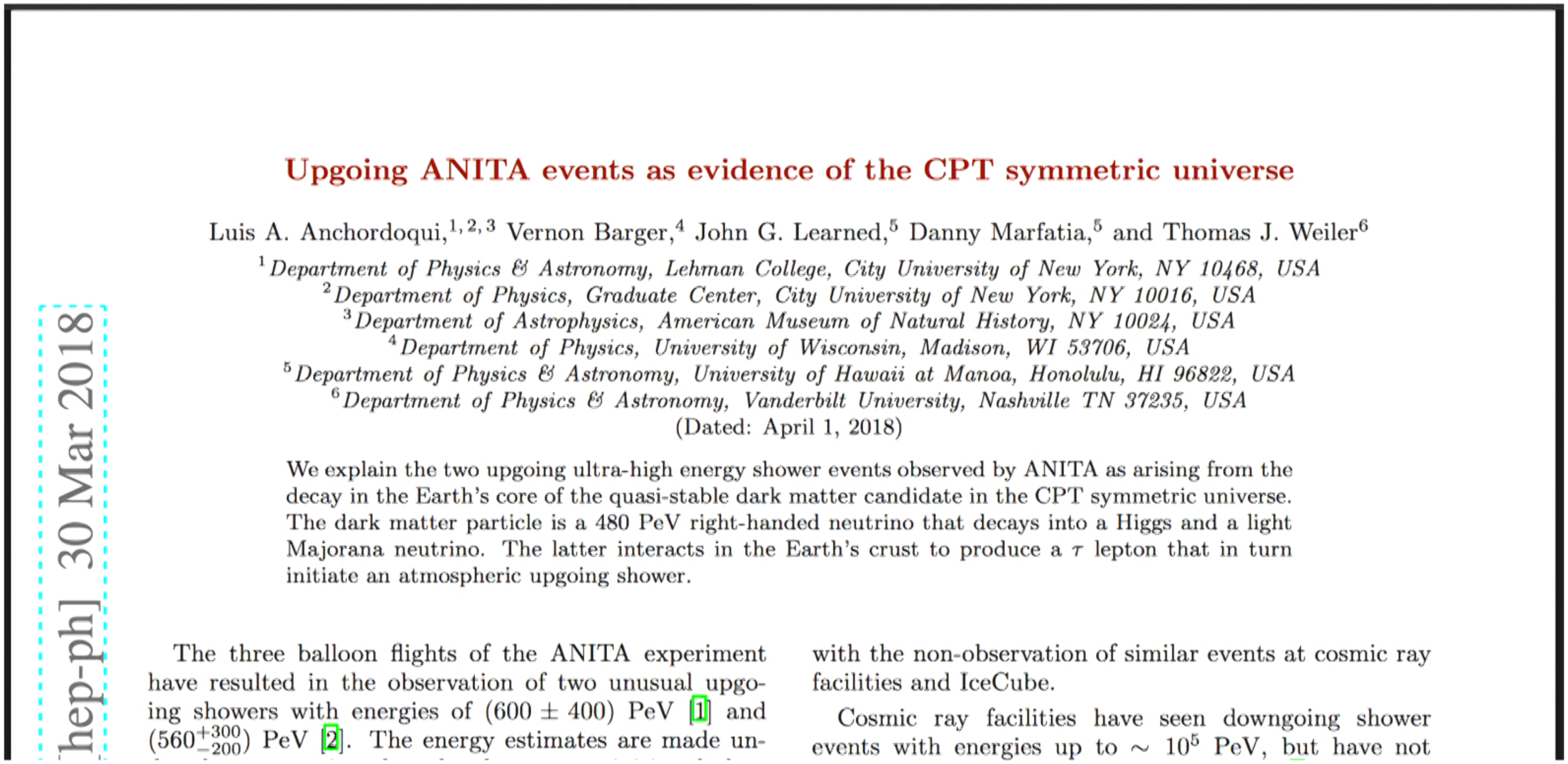
other 2 heavy $\nu's$: leptogenesis



hep-ph] 30 Mar 2018

Upgoing ANITA events as evidence of the CPT symmetric universe

Luis A. Anchordoqui,[1, 2, 3] Vernon Barger,[4] John G. Learned,[5] Danny Marfatia,[5] and Thomas J. Weiler[6]

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[2] *Department of Physics, Graduate Center, City University of New York, NY 10016, USA*
[3] *Department of Astrophysics, American Museum of Natural History, NY 10024, USA*
[4] *Department of Physics, University of Wisconsin, Madison, WI 53706, USA*
[5] *Department of Physics & Astronomy, University of Hawaii at Manoa, Honolulu, HI 96822, USA*
[6] *Department of Physics & Astronomy, Vanderbilt University, Nashville TN 37235, USA*

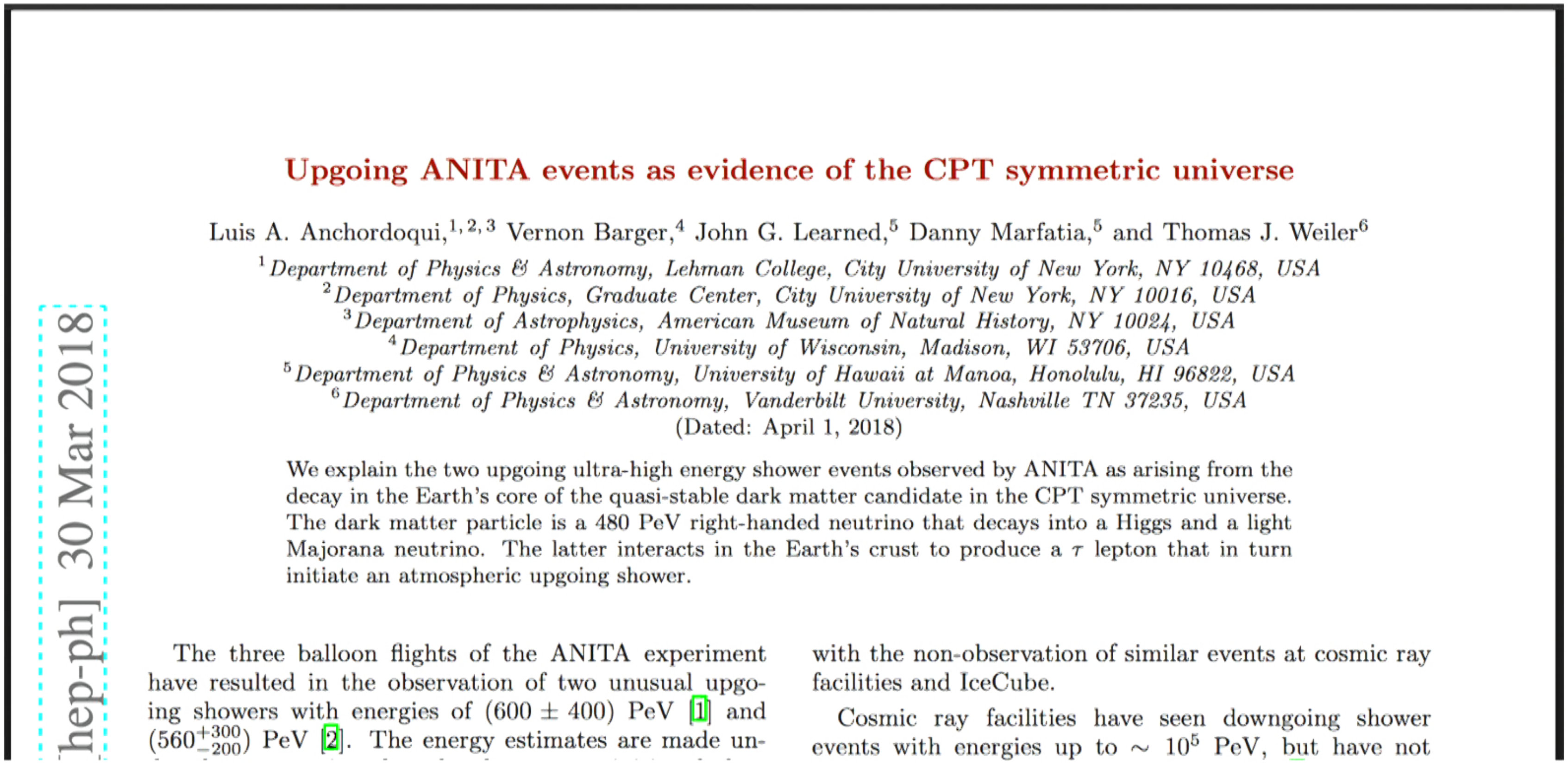
(Dated: April 1, 2018)

We explain the two upgoing ultra-high energy shower events observed by ANITA as arising from the decay in the Earth's core of the quasi-stable dark matter candidate in the CPT symmetric universe. The dark matter particle is a 480 PeV right-handed neutrino that decays into a Higgs and a light Majorana neutrino. The latter interacts in the Earth's crust to produce a τ lepton that in turn initiate an atmospheric upgoing shower.

The three balloon flights of the ANITA experiment have resulted in the observation of two unusual upgoing showers with energies of (600 ± 400) PeV [1] and (560^{+300}_{-200}) PeV [2]. The energy estimates are made un-

with the non-observation of similar events at cosmic ray facilities and IceCube.

Cosmic ray facilities have seen downgoing shower events with energies up to $\sim 10^5$ PeV, but have not



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- in progress: Why is the universe flat FRW plus nearly scale-invariant perturbations?
    - 1st level: quantum fields on classical spacetime
    - 2nd level: one-loop corrections
    - 3rd level: quantum amplitude for U-Ubar pair
- through-the-bang references:
    - Bars, Chen, Steinhardt, Turok: arXiv:1105.3606, 1112.2470, 1207.1940, 1307.1848
    - Gielen, Turok: arXiv:1510.00699, 1612.02792
    - Barbour, Koslowski, Mercati, Sloan: arXiv:1409.0917, 1507.06498, 1604.03956, 1607.02460